

## 2.5 CANAL ROUTING

### Basic Principles

Canal or channel flow routing in the South Florida Water Management Model uses a mass balance approach to account for any changes in storage within a canal reach given beginning-of-day canal stage, canal and structure properties, and calculated or specified inflows and outflows. The mass balance is performed every time step (1 day) for each canal reach and involves grid cells through which each canal reach passes. The SFWMM assumes that the width of a canal is constant along its entire length. The model also assumes a wedge-shaped longitudinal canal profile such that a constant offset or head drop, HDC, occurs along the length of each canal reach. This offset can be considered as a pre-defined slope in the hydraulic grade line that represents the average or long-term difference between the stage in the canal at its upstream end and at its downstream end. It is therefore constant with time and independent of the discharge in the channel. This simplification is used in order to trace flow and stages within the canal as a function of space and time unlike traditional distributed flow routing procedures, i.e., solution of the kinematic, diffusion or dynamic wave equations. The components of the canal water budget are rainfall, evapotranspiration, overland flow (cell-to-canal or canal-to-cell), canal seepage, and structure inflows and outflows. Because some of these components are functions of canal stage, an iterative procedure is used to calculate the end-of-day canal stage.

Rainfall into a canal reach varies by grid cell. The volume of precipitation within a canal segment is equal to the depth of rainfall assigned to a particular grid cell multiplied by the surface area of the canal reach located within the grid cell. Evaporation depth within the canal segment is equal to the product of reference crop evapotranspiration rate and open-water coefficient (KMAX) assigned to the grid cell. A canal segment is that portion of a canal reach that fall entirely within a grid cell while a canal reach is a series of canal segments bounded by the canal's primary inlet and outlet structures.

Canals also interact with freewater or ponded water within the grid cell. In contrast to cell-to-cell overland flow, this interaction provides a means for the model to direct runoff from individual grid cells into canals or to account for overbank flow. Runoff enters the canal as lateral sheetflow, and in situations where excessive canal stages occur, water overtops its banks and becomes part of ponded water. The Manning's equation is used to calculate the exchange of canal water with ponded water. Assuming that the canal bisects a grid cell into two 1-mile by 2-mile strips, the slope of the energy grade line, which runs perpendicular to either side of the canal, is assumed to be equal to the ponding depth (not the difference between the stage in the canal and the average stage in the grid cell) divided by one-half of the short side of either strip. This rough approximation, which is equal to one-fourth the length of one side of a grid cell or 0.5 mile, yields satisfactory results. As in the case for cell-to-cell overland flow (refer to Sec. 2.3), Manning's  $n$  in cell-to-canal (or vice versa) overland flow is expressed as a function of ponding depth at the grid cell where a canal segment is located. Manning's  $n$  varies considerably with vegetation or land use type. Based on these flow characteristics, different values of parameter A and b can be used as in Eq. 2.3.19. Version 3.5 of the model assumes that Manning's  $n$  values for cell-to-canal

and canal-to-cell overland flow vary linearly with parameter **A** (Table 2.5.1), i.e. parameter **b** is zero. Sediment distribution, and channel and riverbank irregularities that define different flow regimes depending on the direction of overland flow were not accounted for in the model. Manning's  $n$  may also vary as a function of channel properties such as sediment distribution and riverbank irregularities. This level of detail is not accounted for in the model.

**Table 2.5.1** Values of Parameter **A** Used to Define Manning's  $n$  for Cell-to-Canal or Canal-to-Cell Overland Flow in the South Florida Water Management Model

	Land Use	Type/Description	A
1	urban	low density	0.35
2	agriculture	citrus	0.35
3	wetland	marsh	2.00
4	wetland	sawgrass plains	1.00
5	wetland	wet prairie	2.00
6	rangeland	shrubland (scrub and shrub)	1.00
7	agriculture	row (or truck) crops	0.35
8	agriculture	sugar cane	0.35
9	agriculture	irrigated pasture	0.35
10	wetland	stormwater treatment area and above-ground reservoir	1.50
11	urban	high density	0.15
12	forest	forested wetlands	1.50
13	forest	mangroves	2.00
14	forest	melaleuca	2.00
15	wetland	cattail	1.00
16	forest	forested uplands	1.50
17	wetland	modified ridge & slough	2.00
18	wetland	marl prairie	1.00
19	wetland	mixed cattail / sawgrass	1.00
20	water	open water (deep excavated reservoirs)	0.01
21	wetland	modified ridge & sawgrass-invaded slough	2.00
22	wetland	cypress prairie (hydrologically similar to wet prairie)	2.00

Land use types 7, 8 and 9 are the three predominant land use classifications in the EAA. Since overland flow is not simulated in the EAA (refer to Sec. 3.3), the coefficients corresponding to these land use types are not used in the model.

Canal seepage describes the interaction of canals with the water table (refer to Sec. 2.4). The operation of structures are site-specific and are discussed, as necessary, throughout this documentation. Canal water budget calculations for a typical canal reach is explained next.

## Canal Water Budget

The beginning-of-day stage CHDEP<sub>0</sub> at the most downstream node of a canal reach is set equal to the stage at the end of the previous time step. The canal stage at the most upstream node of the same canal reach is set equal to the stage at the most downstream node plus offset HDC. Canal defined at intermediate nodes are assumed to have stages proportional to their relative distances from the extreme nodes of the reach.

The initial estimate of the end-of-day or equilibrium stage (CHDEP<sup>0</sup>) at the downstream node is assumed to be equal to beginning-of-day stage. Initial change in storage CHSTOR<sup>0</sup> is, therefore, zero. Rainfall and evapotranspiration are calculated for each canal segment using methods described above. Discharge at the downstream structure (typically a weir or pump) is calculated as a function of its headwater (=CHDEP<sup>0</sup>). Discharges elsewhere within the reach (other outlet structures, canal seepage and overland flow) are either prescribed (e.g., historical) or calculated as a function of CHDEP<sup>0</sup> adjusted for their location relative to the most downstream node of the reach and the slope of the hydraulic grade line HDC. HDC is assumed constant and non-negative at all times. It varies only as a function of canal segment.

The net inflow or accumulation ACVOL<sup>0</sup> is calculated using

$$ACVOL^0 = Q_{in} - Q_{out} \quad (2.5.1)$$

where:

$$\begin{aligned} Q_{in} &= RF + OVLNF_{in} + SEEP_{in} + QSTR_{in}; \text{ and} \\ Q_{out} &= ET + OVLNF_{out} + SEEP_{out} + QSTR_{out}. \end{aligned}$$

It should be noted that OVLNF<sub>in</sub>, OVLNF<sub>out</sub>, SEEP<sub>in</sub>, and SEEP<sub>out</sub> are functions of the assumed end-of-day stage. Therefore, they are implicit functions of the unknown stage. QSTR<sub>in</sub> and QSTR<sub>out</sub> may or may not be implicit functions. Solving for the change in storage based on beginning- and assumed end-of-day stages:

$$CHSTOR^0 = (CHDEP^0 - CHDEP_0) * CAREA \quad (2.5.2)$$

where CAREA is the surface area of the canal reach equal to the product of the width and the length of the canal reach.

By definition, canal water budget indicates that the change in storage CHSTOR<sup>i</sup> must be equal to the net inflow or accumulation ACVOL<sup>i</sup>, where i denotes the i<sup>th</sup> iteration within the same time step. The difference is the estimation error given by:

$$\text{ERROR}^0 = \text{CHSTOR}^0 - \text{ACVOL}^0 \quad (2.5.3)$$

Eliminating this error is the objective in establishing a canal water budget. The objective is met by iteratively assuming the end-of-day stage. A positive error implies that the assumed end-of-day stage is overestimated. In order for the canal to experience a change in storage  $\text{CHSTOR}^0$  due to  $\text{CHDEP}^0$  more inflow (or less outflow) should have resulted from the same  $\text{CHDEP}^0$ . Thus, if  $\text{CHSTOR}^0 > \text{ACVOL}^0$ , the new estimate at the downstream stage is made lower than the previous estimate,  $\text{CHDEP}^1 < \text{CHDEP}^0$ . Conversely, if  $\text{CHSTOR}^0 < \text{ACVOL}^0$  the new estimate is raised,  $\text{CHDEP}^1 > \text{CHDEP}^0$ .  $\text{CHDEP}^0$  is incremented (decremented) to  $\text{CHDEP}^1$  based on the magnitude of the error, an initial increment value ( $\text{INC}^0$ ) of 1.0 ft is used. Therefore,

$$\text{CHSTOR}^1 = \text{CHSTOR}^0 + \text{INC}^0 \quad (2.5.4)$$

The calculations enter an iteration loop where Eqs. (2.5.4) and (2.5.1) through (2.5.3) are solved and a stopping criteria is tested. If the value of  $\text{ERROR}$  changes sign, the magnitude of the increment in stage is halved to prevent oscillation between successive stage estimates. (The number of iterations is the number of times the assumed equilibrium stage is updated.) The iteration loop is terminated when either of the following stopping criteria are met: (a) the absolute value of  $\text{ERROR}/\text{CAREA}$  becomes less than the convergence value (0.01 ft); or (b) the maximum allowable number of iterations (30) has been reached.

The above calculations are performed for all canal reaches in the model domain except for those in the EAA. Conveyance considerations in the major EAA canals are discussed in Sec. 3.3. Overland flow calculations involving canals account for approximately 25% of the total SFWMM run time.